THE ASYMMETRIC IMPULSE OF THE SUNSHINE EFFECT ON STOCK RETURNS AND VOLATILITIES

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Abstract
This study constructs a variety of GARCH models with the consideration of the generalized error distribution to analyze the relationship between the cloud cover and stock returns in Taiwan in the whole sample period (1986 to 2007) and in the two sub-sample periods (1986 to 1996 and 1997 to 2007). The data include Taiwan Stock Exchange Capitalization Weighted Stock Index and the U.S. Dow Jones Industrial Average index to proxy the impact of U.S. stock market on Taiwan's stock market performance. The empirical finding of this study could be used to reconfirm the existence of the so-called sunshine effect. The empirical results suggest that the cloud cover has significantly negative impact on Taiwan's stock market, especially in the low cloud cover periods. Moreover, we also examine the sunshine effect with the consideration of the first and second moments and find that when adding the two moments, the sunshine effect is not significant in the stock returns but in the stock return volatilities, which is different from outcomes in previous studies.

Keywords: behavior finance, stock returns, stock volatility, Sunshine effect, Threshold model

JEL Classification: C22, G10, G12.

Introduction

There are two popular theoretical foundations to analyze investor's behaviors in the stock market in recent studies. One is to assume that the investors are totally rational and another is to presume that the investors are only partially rational. Theoretical models in the first category include the capital asset pricing model (CAPM) proposed by Sharpe (1964), Lintner (1965), and Black (1972), and the efficient market model proposed by

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Fama(1970)[1]. These two models are employed by many other researchers in the fields of macroeconomics or finance to investigate investment efficiency, stock returns, stock prices, or company expectations. For instance, Black, *et al*. (1972), Fama and MacBeth (1973), and Tinic and West (1986) develop a variety of multivariate models to enhance estimation results and to better examine the above mentioned research topics. Models belonging to the second category introduce psychology into economics and finance. The researchers investigate factors affecting investment behaviors through psychological theories such as cognitive bias. Examples include Tversky and Kahneman (1974), and Kahneman and Tversky (1979), the studies first marrying psychology to economics and finance. The authors employ the prospect theory to give new meanings to the behaviors or phenomena that are used to be views as irrational or abnormal behaviors in the stock market, which in turn, introduces a new research methodology in this area.

What is the relationship between sunshine and investment behaviors? Psychologists find that sunshine has unexpected impacts on the psychological sides of human beings. One of the famous and scientifically proved findings is the seasonal affective disorder. Since this symptom is often shown in the winter, it is also called the winter blue. The symptom could be released by exposing the patients under the sun or a special sunshine-like light. What is interesting is that Kamstra *et al.* (2003) find that the SAD would affect stock returns.

In this study, “good weather” is defined as the weather with low sky cover and full of sunshine. In this kind of weather, people are calmer and happier. With the same rationale, we define “bad weather” as the weather with heavy cloud and slim sunlight. In this kind of weather, people would feel moody and unhappy. The weather affects investment behaviors through its impact on people’s psychological status. In the good weather, people are more positive and optimistic about the economy’s futures, so they tend to buy stocks. For instance, Schwarz and Clore (1983), and Howarth and Hoffman (1984) find that people feel happier in sunny days than in cloudy days; therefore, they tend to buy stocks, which in turn causes stock returns to raise in sunny days.

Saunders (1993) is the first study to employ the cloud cover (as the proxy of the sunshine effect) as the explanatory variable. The author uses weather related factors (cloud cover, daily rainfall, and daily snowfall), the Dow Jones Industrial Average (DJIA) index, and the New York Stock Exchange (NYSE) composite index as explanatory variables and proves the existence of the sunshine effect. Many other studies follow Saunders (1993) to examine the impacts of the cloud cover on stock returns. Researches such as Kamstra *et al.* (2003), and Goetzmann and Zhu (2005) all find that the sunshine effect does exist. Dowling and Lucey (2005) agree that investors’ psychological status would affect their investment decisions, but find that the weather factor that impact Ireland’s stock returns is not the cloud cover, but the daily rainfall.

Hirshleifer and Shumway (2003) and Chang *et al.* (2006) all include Taiwan’s stock market in their samples and find that stocks returns are significantly correlated with the cloud cover. Hirshleifer and Shumway (2003) employ 26 stock markets as their sample and use

[1] Efficient market theory assumes that when making decisions, the investors are able to utilize all information, so stock prices could reveal all market information. The establishment of this theory is not only an indication of the healthiness of the market, but also a fundamental assumption of many financial theories. In an efficient market, stock prices would immediately and perfectly reflect all market related information.

daily data from 1982 to 1997 to construct a panel data structure to investigate the relationship between the cloud cover and stock returns[2]. The empirical findings show that "good weather" encourages people to feel positive and optimistic, that psychological status affects people's expectations toward the economy's futures, and that weather would significantly impact daily stock returns. Adding rainy days and snowy days in the regression as explanatory variables, the authors find that this does not change the empirical findings much. However, if investors' trading strategies are based on the weather, the authors find that stock returns is too low so the sunshine effect is not a good trading standard.

Chang *et al.* (2006) employ three weather factors (cloud, temperature, and humidity) and daily stock returns from July 1st, 1997 to October 22nd, 2003, and construct three types of GJR-GRACH (1, 1) models to investigate the relationship between Taipei's weather and Taiwan's stock market returns. Moreover, the authors use the weather factors as the threshold variables to evaluate whether different weather factors would have different impact on the relationship between the weather and the stock returns. The model is specified as follows:

$$R_t = \beta_0 + \sum_{i=1}^{p} \psi_i R_{t-i} + \beta_1 I^+(W_t > \tau)W_t + \beta_2 I^-(W_t \le \tau)W_t + \varepsilon_t \quad \varepsilon_t|\Omega_{t-1} \sim N(0, h_t), \tag{1}$$

$$h_t = \alpha + \theta h_{t-1} + \gamma\varepsilon_{t-1}^2 + \delta\varepsilon_{t-1}^2 I_{t-1} \tag{2}$$

where R_t is the stock return; W_t denotes the cloud cover. I^+ and, I^- are the dummy variables for the cloud cover; τ is the threshold value. If $I^+ = 1$, this indicates that the cloud cover is greater than the optimal threshold value ($W_t > \tau$); if $I^- = 1$, this indicates that the cloud over is smaller than or equal to the optimal threshold value ($W_t \le \tau$). I_{t-1} is the dummy variable for the asymmetric information situation in the stock market. The asymmetric information exists if $I_{t-1} = 1$ where $\varepsilon_{t-1} < 0$; otherwise, $I_{t-1} = 0$. The empirical result of Chang *et al.* (2006) shows that the cloud cover has significant impact on Taiwan's stock returns.

The two above introduced studies have two common problems. The first problem is about the sample period. The samples of both Hirshleifer and Shumway (2003) and Chang *et al.* (2006) are around 1997 and these two articles find that the sunshine effect exists in Taiwan's stock market. From the comparison of the empirical, we think it is necessary to compare the empirical results using samples before and after 1997 to reconfirm the existence of the sunshine effect. The second problem is regarding the model. Hirshleifer and Shumway (2003) just employ a symmetric model to conduct the empirical analysis without the consideration of the possible asymmetry associated with stock index fluctuations. It is well known that the avoidance of the asymmetry would lead to biases in the estimation. Although Chang *et al.* (2006) combine the threshold model and the GJR-

[2] The daily cloud cover data are the averages of the observation values from 6 AM to 4 PM.

GARCH model in the empirical study to incorporate the asymmetry of the stock index fluctuations, the model does not include the impact of the U.S. stock market performance on Taiwan's stock market. This is the area that the Chang *et al.* (2006) model needs to be revised to obtain more accurate estimation results[3].

Summarized from previous studies we find that sunny (cloudy) days encourage people to be positive (negative) and optimistic (pessimistic). Affected by the optimistic (pessimistic) psychological status, investors tend to over (under) evaluate their prospects toward the economy's future, so they will purchase (sell) more stocks. This is the phenomena that investment decisions are misled by the weather, which is also the linkage between the weather and stock returns. Although some studies have proven that sunny days or sunlight are significantly and positively correlated with stock returns, others object to this conclusion. For instance, Goetzmann and Zhu (2005) find that the effectiveness of the so-called sunshine effect would be affected by adding other variables in the estimations. This finding indicates that the primary reason why the sunshine effect is not robust might be that some important variables are missing in previous studies or that the model specification might be not appropriate in those studies.

We summarize the shortcomings of above discussed studies as follows. First, these studies do not consider the possible non-normal distributions of the stock returns. Second, these studies do not take into account the impact of the U.S. stock market performance on the local stock markets. Third, it is well known that there exist the so-called co-movement phenomena in the first and second moments, which indicates that stock market's sunshine effect could come from the first moment, the second moment, or both. However, previous studies do not clarify the source of the sunshine effect. In the present study, we try to revise these shortcomings with the following methods. We focus on Taiwan's stock market and construct a GJR-GARCH model with the consideration of the generalized error distribution (GED) specification and the impact from the performance of U.S. stock market. We build three sunshine effect models: the one only considering the first moment, the one only considering the second moment, and the one considering both the first and the second moments. The estimation results of the three models would tell us the source of the sunshine effect.

The primary tasks of this study could be summarized as follows. First, under the assumption of GED and the consideration of the impact of U.S. stock market performance, we investigate the impacts of the cloud cover and the asymmetries of the stock index fluctuation on stock returns. Second, we divide the whole sample period into tow sub-sample periods, 1986 to 1996 and 1997 to 2007, to compare empirical findings. Third, we switch the clover cover from the mean equation to the variance equation to investigate the impact of the sunshine effect on the volatility of stock returns. If the impact is significant, then we put cloud cover in both the mean and variance equations to identify the source of the sunshine effect.

There are four sections in this paper. The first section is the introduction. The empirical methodology and model are introduced in section two. Section three discusses the empirical results and section four is the conclusion.

[3] Many studies find that the U.S. stock market performance has significant impact on Taiwan's stock market. Examples include Liu and Pan (1997), Chou et al. (1999), Ng (2000), etc.

1. The models

When conducting the empirical analysis, we first employ the threshold model to obtain the optimal threshold value, and then we use this threshold value to construct an asymmetric GARCH model. The threshold model is a popular nonlinear model first proposed by Tong (1978) and Tong and Lim (1980) under the name threshold autoregressive (TAR) model. Using the economic or financial stationary variable as the threshold variable to divide several regimes, the model could be utilized to estimate nonlinear specifications [4]. Compared with linear models, the TAR model has the advantage of obtaining various estimation results. In addition, researchers could analyze the estimation results in each regime and utilize the relationship between the threshold variables and the threshold values to derive economic or financial explanations or provide useful policy suggestions. Hence, the TAR model is widely employed by many researchers to discuss economic or financial issues. For example, Tsay (1998), Hansen (1999), and Huang *et al.*(2005) utilize single or multi-variables TAR models to investigate subjects regarding finance, output, or price fluctuations.

Since the prices of financial products, such as the exchange rate or price index, are characterized by the so-called clustering phenomena, the variances of these prices are not stable but time varying. Although the GARCH model could capture the volatility clustering phenomena, this model cannot catch the asymmetry effect caused by the positive or negative information in the market. Antoniou *et al.* (1998) point out that when the market reactions toward positive and negative news are asymmetric, the GARCH model would bias the estimation results[5]. On the other hand, the GJR-GARCH model has the property to capture the volatility, which in turn, helps to reveal the phenomena of volatility clustering, leptokurtic distribution, and asymmetry of the data. Engle and Ng (1993) compare the EGARCH and GJR-GARCH models and find that when the volatility is asymmetric, the estimation results of the GJR-GARCH model can better reveal this characteristic.

In this study, we utilize the threshold model and the GJR-GARCH model to expand the empirical model of Chang *et al.* (2006) introduced in equations (1) and (2). In addition to the cloud cover threshold index variable, we add last period's return of the DJIA index as an exogenous variable to proxy the influence of U.S. stock market on Taiwan's stock market performance. We specify a GJR-GARCH (1, 1) model with the GED specification to let the stock returns follow the leptokurtic distribution. The first-moment-sunshine-effect model is specified as equations (3) to (6):

$$R_t = \beta_0 + \sum_{i=1}^{p} \psi_i R_{t-i} + \eta R_{t-1}^{DJ} + \beta_1 I^{+}(W_t > \tau) W_t + \beta_2 I^{-}(W_t \geq \tau) W_t + \varepsilon_t \qquad (3)$$

$$h_t = \alpha + \theta h_{t-1} + \gamma \varepsilon_{t-1}^2 + \delta \varepsilon_{t-1}^2 I_{t-1} \qquad (4)$$

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4 When there are multi-variables, one should use the threshold vector autoregressive (TVAR) model. In the TVAR model, all the variables, including the threshold variable, are treated as endogenous, which could better reveal the correlation among variables.

5 Engle (1982) first proposes the autoregessive conditional heteroskedasticity model (ARCH Model) and Bollerslev (1986) develops the generalized ARCH model (GARCH model). There are several derivatives of the GARCH model. Please refer to Bollerslev *et al.* (1992) for detailed discussions.

where R_t = log(P_t/P_{t-1}) × 100 is the returns of the Taiwan Stock Exchange Capitalization Weighted Stock Index; R_{t-1}^{DJ} is lag one-period return of the DJIA index; τ is the threshold value. I^+ and I^- are dummy variables. If $W_t > \tau$, then $I^+ = 1$; if $W_t \le \tau$, then $I^- = 1$. I_{t-1} is a dummy variable as well. If $\varepsilon_{t-1} < 0$, then $I_{t-1} = 1$, otherwise, $I_{t-1} = 0$.

The GED probability density function of the error is:

$$f(\varepsilon_t) = \frac{v \ \exp[-(1/2)\,|\,\varepsilon_t/\lambda\,|^v\,]}{\lambda\, 2^{[(v+1)/v]}\,\Gamma(1/v)} \tag{5}$$

where $\Gamma(.)$ is a Gamma function; $\lambda = \left\{ \frac{2^{(-2/v)}\Gamma(1/v)}{\Gamma(3/v)} \right\}^{1/2}$ is a fixed value; v is a positive parameter standing for the heaviness of the distribution tail. When $v = 2$, $\lambda = 1$ and equation (5) becomes the normal distribution. When $v < 2$, the distribution tail is heavier than that of the normal distribution; when $v > 2$, the distribution tail is thinner than that of the normal distribution. The expectation value of the absolute value of ε_t is:

$$E\ |\,\varepsilon_t\,| = \frac{\lambda\, 2^{(1/v)}\,\Gamma(2/v)}{\Gamma(1/v)} \tag{6}$$

If the distribution is normal, then $E\ |\,\varepsilon_t\,| = \sqrt{2/\pi}$.

Empirical studies of previous researches all focus on the first moment and ignore the second moment. Since the stock return (or stock market index fluctuation rate) has the tendency of co-movement with volatility, once the volatility is expected to occur, one would know that the stock return is about to change. Basing on this argument, we adjust our model to include the second moment:

$$R_t = \beta_0 + \sum_{i=1}^{p} \psi_i R_{t-i} + \eta R_{t-1}^{DJ} + \varepsilon_t \tag{3'}$$

$$h_t = \alpha + \theta\, h_{t-1} + \gamma \varepsilon_{t-1}^2 + \phi_1 I^+(W_t > \tau) + \phi_2 I^-(W_t \le \tau) + \delta \varepsilon_{t-1}^2 I_{t-1} \tag{4'}$$

Equations (3') and (4') are modified from equations (3) and (4) to include the second moment. If the coefficient of the cloud cover in the variance equation is significant, then it means that the second moment is one of the sources causing the sunshine effect. In this case, we would combine equations (3) and (4') to simultaneously examine both the first and second moments. The significant levels of the coefficients of the cloud cover in the mean and variance equations tell the sources of the sunshine effect: first moment (stock returns), the second moment (the stock return volatility), or both.

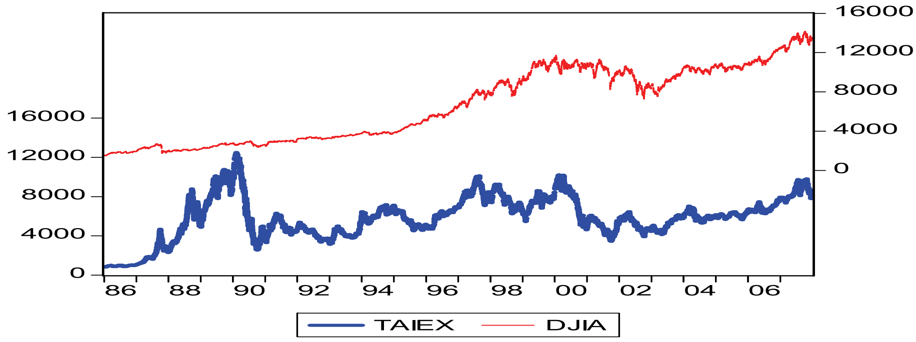
2. Empirical analyses

2.1 The data

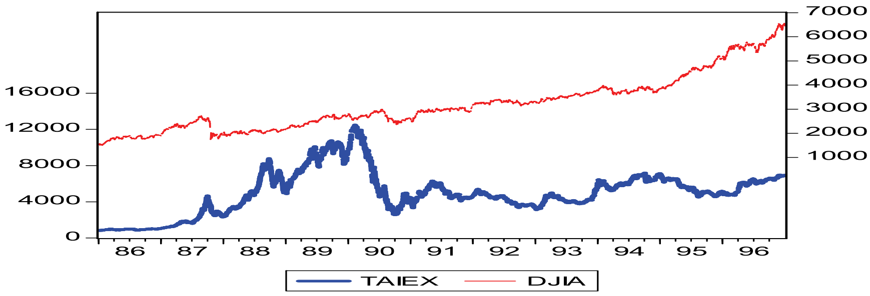
Data of the daily cloud cover come from the Central Weather Bureau of Taiwan. We average the observed data from 5 AM to 2 PM of the Taipei Observation Station to avoid the noises of the cloud cover fluctuations from non-observation time periods. The daily data of the Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX) and the U.S. Dow Jones Industrial Average index (DJIA) come from Taiwan Stock Exchange Company and the AREMOS Database of the Taiwan Economic Data Center, respectively. The study period is from January 1986 to December 2007, which covers 22 years and yields 5,196 observations. Since the Asian financial crisis occurred in 1997, we divide the whole sample into two sub-samples, one from 1986 to 1996 and another from 1997 to 2007, to compare the sunshine effects before and after the Asian financial crisis. Please refer to Appendix A for detailed data descriptions and codes.

Since U.S. is the largest economy in the world, we believe the performance of the U.S. stock market should in some way affects Taiwan's stock market. To examine the existence of this relation, we plot the time series and calculate the correlation coefficients of these two variables. Figure no. 1 shows the time trends of TAIEX Index and the DJIA index in the whole sample period (1986 to 2007) and in the two sub-sample periods (1986 to 1996 and 1997 to 2007). It is very obvious that except for the period of 1987 to 1991, the two indices move in the same direction. Comparing the trends in the two sub-sample periods, we find that the DJIA index is more stable in the first sub-sample period, while the TAIEX index in the second sub-sample period. Table no. 1 lists the correlation coefficients of these two indices in the three sample periods. All the coefficients are statistically significant. The correlation is relatively lower in the first sub-sample period, which corresponds to the finding in Figure no. 1. In addition, Taiwan's stock returns are highly correlated with last day U.S. stock returns. Since Taiwan and U.S. locate in different time zones, the correlation makes perfect sense. In conclusion, the TAIEX index is highly correlated with previous-day DJIA index; this is also the findings in many studies (for instance, Liu and Pan, 1997, Chou *et al.*, 1999, Ng, 2000, and Wang and Cheng, 2003). This is the primary reason why we employ the lag one-period DJIA index in the following regressions[6].

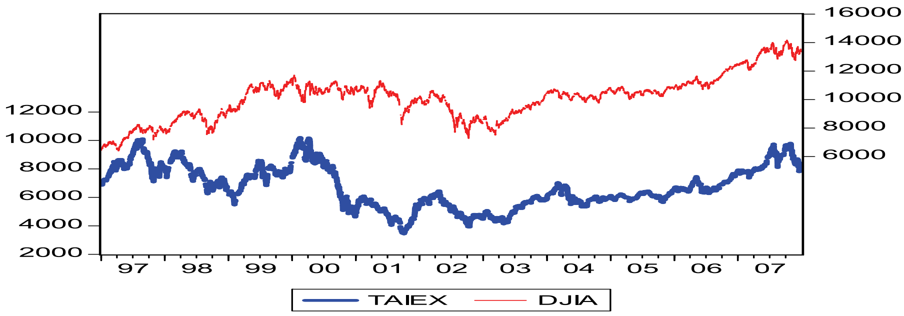
[6] From the international trade aspect to explain the use of the DJIA index, we think that Taiwan is a small open economy and its economic growth relies heavily on exports. The U.S. is not only the largest economy in the world, but also one of the major countries with which Taiwan has a large and long-run trade surplus. Since the pattern of a country's stock index could reveal the future development of that economy, when the U.S. is experiencing an economic boom, the DJIA index would have already reflected this situation one moment earlier. In the meantime, Taiwan's economy would benefit from the economic boom in U.S. by exporting more, and this will be reflected by the TAIEX index. Therefore, it is reasonable to employ the previous-day DJIA index as one of the explanatory variables.



The whole sample period (1986 to 2007)



The first sub-sample period (1986 to 1996)



The second sub-sample period (1997 to 2007)

Figure no. 1: The patterns of the TAIEX and the DJIA indices

Table no. 1: The correlation coefficients of the returns of the TAIEX index (R) and the DJIA index (R^{DJ})

The whole sample period (1986 to 2007)					
	R_t	R_t^{DJ}		R_t	R_{t-1}^{DJ}
R_t	1	0.024**	R_t	1	0.155**
R_t^{DJ}		1	R_{t-1}^{DJ}		1

The first sub-sample period (1986 to 1996)					
	R_t	R_t^{DJ}		R_t	R_{t-1}^{DJ}
R_t	1	0.004**	R_t	1	0.086**
R_t^{DJ}		1	R_{t-1}^{DJ}		1

The second sub-sample period (1997 to 2007)					
	R_t	R_t^{DJ}		R_t	R_{t-1}^{DJ}
R_t	1	0.048**	R_t	1	0.262**
R_t^{DJ}		1	R_{t-1}^{DJ}		1

*Note: R_t , R_t^{DJ} , and R_{t-1}^{DJ} stand for the stock returns of the TAIEX, the current DJIA, and lag one-period DJIA indices. The Pearson correlation coefficients are calculated. ** denotes the 5% significance.*

In Table no. 2, we summarized the basic statistics and the correlation coefficients of the cloud cover and the TAIEX index for the whole and two sub-sample periods. Panel A of Table no. 2 shows that the means of the cloud cover in all sample periods are positive. The skewness and kurtosis coefficients indicate that the distribution of the cloud cover is skewed to the left and belongs to the platykurtic distribution. The highest cloud cover is in the first sub-sample period and the J-B statistic indicates that the cloud cover does not follow a normal distribution. As to the return of the TAIEX index, in the three sample periods the means of the returns are all positive. The return in the first sub-sample period is greater than that of the second sub-sample period, which indicates that there were harmful events to Taiwan's stock market in the second sub-sample period. The skewness and kurtosis coefficients indicate that the distribution of the return of the TAIEX index is skewed to the right and belongs to the leptokurtic distribution. The J-B statistic indicates that the TAIEX index does not follow a normal distribution in the whole sample period, but in years of 1987, 1998, 2000, and 2005, the normal distribution assumption cannot be rejected. We employ the Quantile-Quantile plot in Figure no. 2 to reconfirm the normality of this variable and the results indicates that in the three sample periods, the TAIEX index does not follow a normal distribution[7]. Summarizing from the findings of the J-B test and the Quantile-Quantile plot we conclude that the TAIEX index does not obey a normal distribution. Panel B of Table no. 2 reports the correlation coefficients of the cloud cover and the TAIEX index in the three sample periods. It is very obvious that these two variables are negatively correlated and this negative correlation is stronger in the second sub-sample period.

Table no. 2: The basic statistics and the correlation coefficients of the variables

Panel A	(Average) cloud cove (W)					Returns of the TAIEX index				
Period/year	Mean	Standard deviation	Skewness	Kurtosis	J-B statistic	Mean	Standard deviation	Skewness	Kurtosis	J-B statistic
1986~1997	7.43	2.68	-0.90	2.66	727.26**	0.06%	0.02	0.13	5.76	1527.87**
1986~1996	7.55	2.72	-0.97	2.81	637.99**	0.07%	0.02	-0.19	5.44	641.56**
1986	7.34	2.90	-0.81	2.36	46.58 **	0.07%	0.01	-0.67	3.97	25.85**
1987	7.49	2.85	-1.02	2.87	63.57 **	0.23%	0.02	-0.27	2.77	**3.38**
1988	7.65	2.74	-1.07	3.00	69.95 **	0.20%	0.02	-0.37	2.29	10.41**
1989	7.62	2.86	-1.13	3.11	78.77**	0.25%	0.02	0.57	6.91	157.37**
1990	7.62	2.56	-0.94	2.68	55.15**	-0.31%	0.04	-0.06	2.21	5.98**
1991	7.90	2.33	-1.10	3.38	76.17**	0.05%	0.02	-0.27	4.38	20.91**
1992	7.88	2.62	-1.18	3.21	85.90**	0.00%	0.01	-0.39	5.50	65.63**
1993	7.37	2.74	-0.72	2.36	37.71**	0.18%	0.02	0.42	4.13	19.81**
1994	7.40	2.75	-0.88	2.69	49.22**	0.03%	0.01	-0.39	7.01	160.56**
1995	7.62	2.51	-0.95	2.95	54.99**	-0.10%	0.01	-0.15	5.13	44.51**
1996	**7.17**	**2.93**	-0.77	2.31	43.07**	**0.12%**	0.01	-0.56	9.46	407.08**
1997~2007	7.49	2.62	-0.88	2.60	544.32**	0.05%	0.01	0.05	4.90	355.36**
1997	7.52	2.62	-0.88	2.59	49.61**	0.11%	0.01	-0.30	4.87	36.81**
1998	7.84	2.44	-1.05	3.00	66.72**	-0.02%	0.01	0.32	3.72	**8.40**

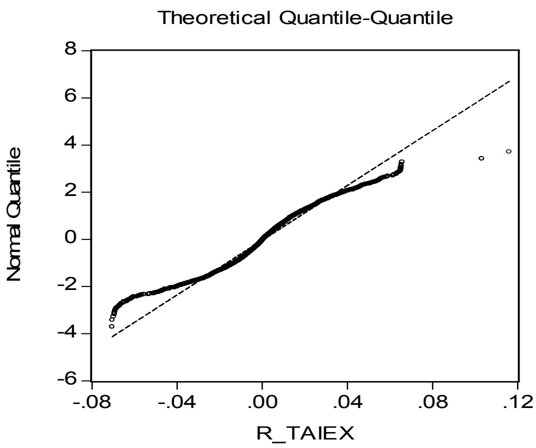
[7] The method of the Quantile-Quantile plot works as follows. It samples from the given sample first. After standardizing the new samples, it then calculates the means and variances and sort these calculated statistics. The corresponding standard normal values of these statistics can be obtained from the standard normal distribution table. Marking the sorted standardized sample values on the horizontal axis and the corresponding standard normal values on the vertical axis, one could get the Quantile-Quantile plot. If the sample line overlaps with the standard normal line, then the given sample follows a normal distribution.

Panel A	(Average) cloud cove (W)					Returns of the TAIEX index				
Period/year	**Mean**	**Standard deviation**	**Skewness**	**Kurtosis**	**J-B statistic**	**Mean**	**Standard deviation**	**Skewness**	**Kurtosis**	**J-B statistic**
1999	7.87	2.46	-1.22	3.58	96.21**	0.07%	0.02	-0.21	5.09	40.27**
2000	7.85	2.50	-1.07	2.95	69.48**	-0.08%	0.02	0.23	3.61	**5.16**
2001	7.43	2.71	-0.92	2.74	52.41**	0.21%	0.02	0.25	2.98	1.98
2002	7.11	2.78	-0.64	2.16	36.48**	0.01%	0.02	0.54	3.46	11.62**
2003	7.07	2.68	-0.58	2.07	33.60**	0.05%	0.01	0.00	4.15	10.57
2004	**6.90**	**2.85**	-0.53	1.94	34.03**	**0.08%**	0.01	-0.43	6.26	94.11**
2005	7.58	2.63	-1.00	2.86	60.89**	0.02%	0.01	0.11	3.23	**0.83**
2006	7.58	2.49	-0.93	2.77	53.97**	0.08%	0.01	-0.68	5.63	70.22**
2007	7.67	2.44	-0.93	2.83	52.68**	0.02%	0.01	-1.06	5.49	84.51**

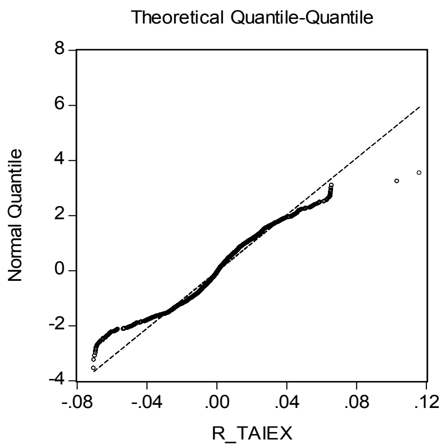
Panel B The correlation coefficient table

Period	1986 to 2007		1986 to 1996		1997 to 2007	
	R_t	W_t	R_t	W_t	R_t	W_t
R_t	1	-0.0010**	1	-0.0007**	1	-0.0015**
W_t		1		1		1

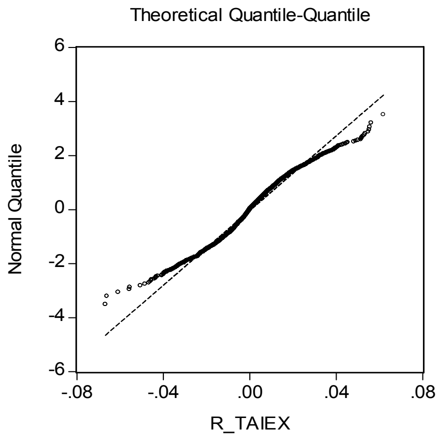
*Note: The J-B statistic denotes the Jarque-Bera statistic that is used to test whether the standardized error follows a normal distribution. ** stands for the 5% significance. The Pearson correlation coefficients are calculated to perform the hypothesis test of the correlation of two variables.*



The Quantile-Quantile plot of the TAIEX index in the whole sample period



The Quantile-Quantile plot of the TAIEX index in the first sub-sample period



The Quantile-Quantile plot of the TAIEX index in the second sub-sample period

Figure no. 2: The Quantile-Quantile plots of the returns of the TAIEX index in the three sample periods

We summarize the findings in Tables no. 1 and 2 as follows. First, since the return of the TAIEX index differs before and after 1997, it is necessary to estimate and compare the results in the sub-sample periods. Second, the return of the TAIEX index does not follow a normal distribution, so it is more appropriate to estimate with the GED specification. Third, the previous-day DJIA index return is significantly related to the return of TAIEX, so the previous-day DJIA index return should be included in the model. Fourth, the unconditional correlation coefficients show that the cloud cover and the return of the TAIEX index have significantly negative relationship, so it is reasonable to examine the existence of the sunshine effect in Taiwan's stock market.

2.2 The unit root test

Table no. 3 reports the unit-root test result. We employ the augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test to examine the stationarity of the variables (cloud cover, TAIEX index returns, and the DJIA index returns). The test result indicates that all the variables are I(0), which means that we could directly use them to estimate the model.

Table no.3: The unit root test

Rate of returns	**ADF**				**PP**			
Whole sample period	τ_{μ} **statistic**	**p value**	τ_{μ} **statistic**	**p value**	τ_{μ} **statistic**	**p value**	τ_{μ} **statistic**	**p value**
Cloud cover	-12.79**	(0.00)	-12.83**	(0.00)	-51.39**	(0.00)	-51.35**	(0.00)
TAIEX index	-17.71**	(0.00)	-17.76**	(0.00)	-68.55**	(0.00)	-68.49**	(0.00)
DJIA index	-44.13**	(0.00)	-44.14**	(0.00)	-72.13**	(0.00)	-72.14**	(0.00)
Period: 1986 to 1996								
Cloud cover	-22.77**	(0.00)	-22.78**	(0.00)	-35.81**	(0.00)	-35.80**	(0.00)
TAIEX index	-11.99**	(0.00)	-12.04**	(0.00)	-47.78**	(0.00)	-47.67**	(0.00)
DJIA index	-22.95**	(0.00)	-22.95**	(0.00)	-49.36**	(0.00)	-49.35**	(0.00)
Period: 1997 to 2007								
Cloud cover	-13.43**	(0.00)	-13.47**	(0.00)	-35.13**	(0.00)	-35.29**	(0.00)
TAIEX index	-33.92**	(0.00)	-25.21**	(0.00)	-49.32**	(0.00)	-49.32**	(0.00)
DJIA index	-52.27**	(0.00)	-52.27**	(0.00)	-52.42**	(0.00)	-52.41**	(0.00)

*Note: 1. The ADF and PP unit root tests are performed. τ_{μ} is the unit-root test statistic indicating that the regression includes a constant term. τ_{τ} is the unit-root test statistic indicating that the regression includes a constant term and a time trend. ** stands for the 5% significance. 2. Except for the cloud cover, all other variables are expressed as the rate of returns.*

2.3 The discussion of the empirical results

We construct a uni-variable threshold GARCH (1, 1) model to investigate the existence of the sunshine effect in Taiwan's stock market[8]. In equations (3) and (4), $I^{+}W_t$ indicates the cloud cover is greater than the threshold value, which belongs to a high cloud cover (low sunlight) period; $I^{-}W_t$ indicates the cloud cover is less than or equal to the threshold value, which belongs to a low cloud cover (high sunlight) period. In addition, we want to find the optimal model by comparing the estimation results among different distributions, different model settings, and different sample periods.

[8] The specification of the mean equation is AR (5) that is determined with the considerations of the AIC criterion and no autocorrelation of the error term.

We estimate the following five GARCH models in the whole sample period:

- *Model 1*: The mean equation does not contain the influence of the U.S. stock market on Taiwan's stock market. The variance equation does not consider the impact of the asymmetric information. The error term follows the GED specification.
- *Model 2*: The mean equation does not contain the influence of the U.S. stock market on Taiwan's stock market. The variance equation considers the impact of the asymmetric information. The error term follows the GED specification.
- *Model 3*: The mean equation contains the influence of the U.S. stock market on Taiwan's stock market. The variance equation considers the impact of the asymmetric information. The error term follows the GED specification.
- *Model 4*: The mean equation contains the influence of the U.S. stock market on Taiwan's stock market. The variance equation considers the impact of the asymmetric information. The error term follows the normal distribution.
- *Model 5*: The mean equation does not contain the influence of the U.S. stock market on Taiwan's stock market. The variance equation considers the impact of the asymmetric information. The error distribution follows the normal distribution.

We summarize the model specifications in Table no. 4.

Table no. 4: Model specifications

Mo-del	Esti-mation results listed in Table	Sample period	Mean equation considers U.S. stock market influence	Mean equation considers the sunshine effect	Variance equation considers the sunshine effect	Variance equation considers asy-mmetric effect	Error follows GED speci-ficati-on	Error follows normal distri-bution
1	5	1986~ 2007		●			●	
2	5	1986~ 2007		●		●	●	
3	5	1986~ 2007	●	●		●	●	
4	5	1986~ 2007	●	●		●		●
5	5	1986~ 2007		●		●		●
6	6	1986~ 1996	●	●		●	●	
7	6	1986~ 1996	●	●			●	
8	6	1997~ 2007	●	●		●	●	
9	6	1997~ 2007	●	●			●	
10	6	199707~ 200310	●	●		●	●	

Mo-del	Esti-mation results listed in Table	Sample period	Mean equation considers U.S. stock market influence	Mean equation considers the sunshine effect	Variance equation considers the sunshine effect	Variance equation considers asy-mmetric effect	Error follows GED speci-ficati-on	Error follows normal distri-bution
11	6	199707~ 200310		●		●		●
12 _V	7	1986~ 2007	●		●	●	●	
13 _V	7	1986~ 2007	●		●		●	
14 _V	7	1986~ 1996	●		●	●	●	
15 _V	7	1986~ 1996	●		●		●	
16 _V	7	1997~ 2007	●		●	●	●	
17 _V	7	1997~ 2007	●		●	●	●	
12 _MV	8	1986~ 2007	●	●	●	●	●	
13 _MV	8	1986~ 2007	●	●	●		●	
14 _MV	8	1986~ 1996	●	●	●	●	●	
15 _MV	8	1986~ 1996	●	●	●		●	
16 _MV	8	1997~ 2007	●	●	●	●	●	
17 _MV	8	1997~ 2007	●	●	●	●	●	

Note:● denotes that the indicated action is taken in the corresponding model.

Table no. 5 reports the estimation results of the whole sample period. The impact of the cloud cover on the returns of the TAIEX index is negative in the five models but insignificant in Models 2 and 3. The results in Models 1, 4, and 5 indicate that the impact of the cloud cover on Taiwan's stock returns is larger when the cloud cover is lower than the threshold value. This finding is consistent with the conclusions of the studies that we discussed before. As to the influence of the U.S. stock market, the estimation results of Model 3 and Model 4 show that the previous-day U.S. stock returns have significantly positive impact on the current-day Taiwan's stock returns. This finding is consistent with our analysis of Figure no. 1; therefore, it is necessary to consider the influence of U.S. stock market performance on Taiwan's stock returns. As to the error distribution, estimation results of Models 1, 2, and 3 (the GED specification) show that the GED coefficients are significantly different from 2, which is an indication that the errors do not follow the normal distribution. In other words, the assumption of a normally distributed error term might bias the estimation results. Our empirical results show that in the whole sample period with the GED error distribution, including the influence of U.S. stock market on Taiwan's stock market would reduce the impact of the cloud cover on Taiwan's stock returns, but will not affect the asymmetry of the stock price fluctuations.

Table no. 5 Estimation results of the first-moment-sunshine-effect equation, whole sample period

Period (distri-bution)	**1986 to 2007 (GED specification)**						**1986 to 2007 (normal distribution)**			
	Model 1		Model 2		Model 3		Model 4		Model 5	
Thres-hold value	τ = 1.5		τ = 6.2		τ = 6.2		τ = 6.2		τ = 6.4	
	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value
Con-stant	0.12 **	(0.05	0.15 **	(0.05)	0.12	(0.12)	0.16 **	(0.05)	0.21 **	(0.01)
R_{t-1}	0.03 **	(0.02	0.04 **	(0.01)	0.03 **	(0.03)	0.05 **	(0.00)	0.06 **	(0.00)
R_{t-2}	0.05 **	(0.00)	0.06 **	(0.00)	0.06 **	(0.00)	0.06 **	(0.00)	0.06 **	(0.00)
R_{t-3}	0.03 **	(0.04)	0.03 **	(0.03)	0.02	(0.07)	0.03 **	(0.01)	0.03 **	(0.01)
R_{t-4}	-0.02	(0.16)	-0.02	(0.21)	-0.02	(0.20)	0.00	(0.91)	0.00	(0.87)
R_{t-5}	0.00	(0.83)	0.00	(0.79)	0.00	(0.97)	0.00	(0.97)	0.00	(0.77)
I^+W_t	-0.01	(0.35)	-0.01	(0.21)	-0.01	(0.33)	-0.01	(0.14)	-0.02 *	(0.07)
I^-W_t	-0.22 *	(0.09)	-0.03	(0.11)	-0.02	(0.19)	-0.04 *	(0.07)	-0.05 **	(0.03)
R_{t-1}^{DJ}	NA	NA	NA	NA	0.28 **	(0.00)	0.31 **	(0.00)	NA	NA
Con-stant	0.02 **	(0.00)	0.03 **	(0.00)	0.03 **	(0.00)	0.04 **	(0.00)	0.04 **	(0.00)
ε_{t-1}^2	0.07 **	(0.00)	0.06 **	(0.00)	0.06 **	(0.00)	0.06 **	(0.00)	0.05 **	(0.00)
$\varepsilon_{t-1}^2 I_{t-1}$	NA	NA	0.05 **	(0.00)	0.04 **	(0.00)	0.05 **	(0.00)	0.06 **	(0.00)
h_{t-1}	0.92 **	(0.00)	0.91 **	(0.00)	0.92 **	(0.00)	0.91 **	(0.00)	0.91 **	(0.00)

Period (distri-bution)	**1986 to 2007 (GED specification)**						**1986 to 2007 (normal distribution)**			
	Model 1		Model 2		Model 3		Model 4		Model 5	
GED	1.34 **	(0.00)	1.36 **	(0.00)	1.37 **	(0.00)	NA	NA	NA	NA
Adj R^2	0.007		0.006		0.035		0.036		0.009	
AIC	3.847		3.845		3.809		3.851		3.887	
Log likely-hood	-9971.94		-9964.24		-9870.61		-9981.17		-10075.01	
Q(5)	8.67	(0.12)	8.19	-0.15	5.19	-0.39	0.71	(0.98)	1.95	(0.86)
ARCH (5)	10.11 *	(0.07)	7.72	-0.17	7.57	-0.18	6.79	(0.24)	7.43	(0.19)

Note: R_t *= log(P_t/P_{t-1})*100 denotes the rate of return of the TAIEX index.* R_{t-1}^{DJ} *is last period's rate of return of the DJIA index. * and ** denote the 10% and 5% significances, respectively. Q(k) and ARCH(k) stand for the test statistics of the residual serial correlation and heteroskedasiticity, respectively. k denotes the delay periods. GED and Log likelihood are the estimated GED coefficient and the log likelihood value, respectively.*

Table no. 6 reports the estimation results in the two sub-sample periods. The first sub-sample period is from 1986 to 1996 and the second from 1997 to 2007; each period contains eleven years. Models 6 and 7 cover the first sub-sample period, and Models 8 to 11 cover the second sub-sample period. Please refer to Table no. 4 for the specifications of Models 6 to 11. To compare the estimation results of different model specifications, we specify Models 6 and 8 as GJR-GARCH (1, 1) and Models 7 and 9 as GARCH (1, 1). In addition, to compare our estimation results with Chang et al. (2006), we employ the same sample periods as those of Chang et al. (2006) for Models 10 and 11. The specification of Model 10 is consistent with Model 8, the empirical model in Chang *et al.* (2006). As to the error distributions, except for Model 11, the error terms of the rest models follow the GED specification.

Table no. 6: Estimation results of the first-moment-sunshine-effect equation, sub-sample periods

Period (distribution)	1986~1996 (GED specification)		1986~1996 (GED specification)		1997~2007 (GED specification)		1997~2007 (GED specification)		1997/07~2003/10 (GED specification)		(normal distribution)	
	Model 6		Model 7		Model 8		Model 9		Model 10		Model 11	
Threshold value	τ=6.2		τ=1.5		τ=5.6		τ=5.4		τ=5.6		τ=8.2	
	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff	P value	Coeff.	P value
Constant	0.21*	(0.09)	0.16*	(0.10)	0.19**	(0.05)	0.19*	(0.07)	0.37**	(0.04)	0.26	(0.12)
R_{t-1}	0.04**	(0.04)	0.04**	(0.05)	0.01	(0.72)	0.00	(0.89)	0.02	(0.51)	0.05*	(0.08)
R_{t-2}	0.08**	(0.00)	0.07**	(0.00)	0.04**	(0.04)	0.03*	(0.08)	0.06**	(0.01)	0.07**	(0.01)
R_{t-3}	0.04*	(0.06)	0.03*	(0.08)	0.01	(0.61)	0.01	(0.66)	0.00	(0.97)	0.01	(0.77)
R_{t-4}	-0.01	(0.75)	0.00	(0.80)	-0.03*	(0.09)	-0.03*	(0.06)	-0.02	(0.52)	0.01	(0.69)
R_{t-5}	0.01	(0.77)	0.01	(0.79)	0.00	(0.93)	-0.01	(0.61)	0.00	(0.96)	0.00	(0.90)
$I^{+}W_t$	-0.01	(0.31)	-0.01	(0.44)	-0.02	(0.12)	-0.02	(0.17)	-0.05**	(0.02)	-0.03*	(0.07)
$I^{-}W_t$	-0.04	(0.14)	-0.35*	(0.09)	-0.06**	(0.04)	-0.05*	(0.09)	-0.11**	(0.03)	-0.05*	(0.07)
R_{t-1}^{DJ}	0.16**	(0.00)	0.16**	(0.00)	0.36**	(0.00)	0.37**	(0.00)	0.32**	(0.00)	NA	NA
Variance Equation												
Constant	0.04**	(0.00)	0.03**	(0.00)	0.03**	(0.00)	0.02**	(0.00)	0.19**	(0.00)	0.18**	(0.00)
ε_{t-1}^{2}	0.07**	(0.00)	0.07**	(0.00)	0.04**	(0.00)	0.07**	(0.00)	0.02**	(0.00)	0.00	(0.73)
$\varepsilon_{t-1}^{2} I_{t-1}$	0.02	(0.19)	NA	NA	0.07**	(0.00)	NA	NA	0.14**	(0.00)	0.16**	(0.00)
h_{t-1}	0.91**	(0.00)	0.92**	(0.00)	0.92**	(0.00)	0.93**	(0.00)	0.85**	(0.00)	0.87**	(0.00)
$I^{+}W_t$	NA		NA		NA		NA		NA		NA	
$I^{-}W_t$	NA		NA		NA		NA		NA		NA	
GED	1.37**	(0.00)	1.35**	(0.00)	1.38**	(0.00)	1.35**	(0.00)	1.43**	(0.00)	NA	NA
Adj R^2	0.019		0.020		0.064		0.064		0.055		0.003	
AIC	4.104		4.103		3.511		3.518		3.932		4.02	
Log likelihood	-5272.49		-5272.46		-4566.44		-4576.11		-2924.80		-2993.23	
Q(5)	3.46	(0.63)	3.85	(0.57)	2.14	(0.58)	2.37	(0.80)	1.43	(0.92)	0.19	(1.00)
ARCH(5)	3.77	(0.58)	3.88	(0.57)	9.14	(0.10)	9.35	(0.10)	4.37	(0.50)	4.54	(0.47)

Note: Please refer to Table 5 for the definitions of the notations.

The estimation results in Table no. 6 indicate that the U.S. stock market still has significant influence on Taiwan's stock returns, which means that the influence is independent of model specifications or sample periods. As to the sub-sample period estimations, in the first sub-sample period, the asymmetry of the residual is insignificant in Model 6; this subject (the asymmetry of the residual is not considered in Model 7. The smaller AIC value and the greater maximum likelihood value of Model 7 indicate that the specification of Model 7 is better than that of Model 6, which indicates that GARCH (1, 1) is a more appropriate specification than GJR-GARCH (1, 1) in this case. In the second sub-sample period, comparing the estimation results of Models 8 and 9 we find that the asymmetry of the residual is significant in Model 8 and this model has a smaller AIC value and a greater maximum likelihood value. These findings indicate that the GJR-GARCH (1, 1) specification (Model 8) is more appropriate than the GARCH (1, 1) specification (Model 9) in this case. Because of these estimation results, in the following estimation for the eight industrial stock sectors, we employ the GARCH (1, 1) model for the variance equation in the first sub-sample period estimation and the GJR-GARCH (1, 1) model for the variance equation in the second sub-sample period estimation. Special revisions will be applied to certain stock sectors to meet the basic requirements of econometrics and economics. Comparing the results of Models 10 and 11 we find that Model 10 has a smaller AIC value and a greater maximum likelihood value, which indicates that considering the influence of the U.S. stock market and employing the GED specification would enhance the goodness of fit of Model 10; this also implies that the model of Chang *et al.* (2006) might need to be revised.

Summarizing from the above findings one can see that expanding our sample period and employing a more flexible model, our estimation results provide both supports and suggestions to the findings and model specifications of many previous studies. Moreover, sub-sample estimations in the first and second sub-sample periods, such as the estimations of Models 7 to 11, all suggest that low cloud cover has significantly negative impacts on Taiwan's stock returns. In addition, as shown in Table no. 6, this negative impact is weaker in the first sub-sample period than in the second sub-sample period, which is a finding that has not been discovered in previous studies on this field. As to the asymmetry of the residual, it is insignificant in the first sub-sample period, which can be seen by comparing Models 6 and 7, and significant in the second sub-sample period, which can be found by comparing Models 8 and 9.

Regarding the influence of the U.S. stock market, we find that adding this variable would reduce the impact of the cloud cover on Taiwan's stock returns, which is a finding similar to that of Goetzmann and Zhu (2005). However, in the second sub-sample period, the impact of the cloud cover on Taiwan's stock returns is still significant even though we add the influence of the U.S. stock market. This indicates that the sunshine effect varies with sample periods. In conclusion, our empirical results not only offer supports to the empirical results of Hirshleifer and Shumway (2003), and Chang *et al.* (2006), but also discover new phenomena that have not been seen in previous studies.

In the following, we explain the economic significance of our empirical findings above. The first sub-sample period corresponds to the time that the New Taiwan Dollar (NTD) considerably appreciated. During that period, Taiwan experienced huge inflow of hot money and the target of the money was Taiwan's stock market. Observing the historical pattern of the TAIEX index, one could see a significant upward trend during the first sub-sample period. The afterward global recession badly hit Taiwan's stock market, which caused a significantly downturn of the TAIEX index. Although the sunshine effect could still impact the investors, its influence was largely reduced and could not be compared with the impact of people's expectations. Therefore, we saw an insignificant sunshine effect in the estimations above in the first sub-sample period. In the second sub-sample period, Taiwan faced a series of domestic and international mishaps: the Asian financial crisis in 1997, the historically big earthquake in 1999, the dot-com bubble explosion in 2000, the 911 attack in U.S. in 2001, the spread of the SARS in Taiwan, Hong Kong, and China in 2003, etc[9]. It is fair to say that since the start of the second sub-sample period (1997), there were many natural and man-made disasters in the world. Combined with the mental and physical disturbances caused by entering the new century (for instance, the Y2K issues), these mishaps might make investors more sensitive to the surroundings, which in turn, leads to a significant sunshine effect in the second sub-sample period.

Table no. 7 reports the estimation results of the second-moment-sunshine-effect model. The cloud cover is not included in the mean but in the variance equation. There are two models in the whole sample period, the first-, and the second-sub sample periods, which yields six models in Table no. 7. As one can see that the coefficient of the impact of U.S. stock market performance are significant in all the six models, which is an indication of the robustness of this variable. The sample periods of Models 12 and 13 are from 1986 to 2007; the only difference between the two models is the asymmetry in the variance equation - Model 13 is the symmetric GARCH (1, 1) model while Model 12 is the asymmetric GJR-GARCH (1, 1) model (the coefficient of the asymmetric factor δ is significant). In addition, the AIC value, the maximum likelihood value, and the ARCH test all confirm that Model 12 has better goodness of fit than Model 13 does. Estimation results of Model 12 show that low cloud cover has significantly negative impact on the stock return volatility, which indicates that the sunshine effect comes from the second moment.

[9] Although Taiwan's stock market was not as badly hit by the Asian financial crisis as other Asian stock markets, in 1998, there are several financial scandals in Taiwan and some listed companies facing the risks of going bankruptcy, which caused several disturbances in Taiwan's stock market. This event is called Taiwan's 1998 domestic financial crisis.

Table no. 7: Estimation results of the second-moment-sunshine-effect equation

Period (distribution)	**Model 12 (GED specification)**		**Model 13 (GED specification)**		**Model 14 (GED specification)**		**Model 15 (GED specification)**		**Model 16 (GED specification)**		**Model 17 (GED specification)**	
	1987~2007				1987~1996				1997~2007			
Threshold alue	τ=2.3		τ=2.3		τ=6.7		τ=6.7		τ=2.3		τ=1.7	
	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff	P value	Coeff.	P value
Constant	0.04**	(0.05)	0.05**	(0.01)	0.07**	(0.03)	0.08**	(0.01)	0.02	(0.31)	0.02	(0.47)
R_{t-1}	0.03**	(0.04)	0.03*	(0.06)	0.04**	(0.03)	0.04**	(0.05)	0.01	(0.66)	0.01	(0.49)
R_{t-2}	0.06**	(0.00)	0.05**	(0.00)	0.08**	(0.00)	0.07**	(0.00)	0.04**	(0.04)	0.04**	(0.05)
R_{t-3}	0.02*	(0.07)	0.02*	(0.09)	0.04*	(0.07)	0.03*	(0.08)	0.01	(0.59)	0.00	(0.80)
R_{t-4}	-0.02	(0.21)	-0.02	(0.14)	0.00	(0.87)	-0.01	(0.78)	-0.03*	(0.10)	-0.03*	(0.09)
R_{t-5}	0.00	(0.98)	0.00	(0.71)	0.01	(0.78)	0.00	(0.86)	0.00	(0.92)	0.00	(0.92)
$I^{+}W_t$	NA		NA		NA		NA		NA		NA	
$I^{-}W_t$	NA		NA		NA		NA		NA		NA	
R_{t-1}^{DJ}	0.28**	(0.00)	0.29**	(0.00)	0.16**	(0.00)	0.16**	(0.00)	0.36**	(0.00)	0.35**	(0.00)
Variance Equation												
Constant	0.04	(0.15)	0.04	(0.11)	0.16**	(0.05)	0.16**	(0.05)	0.07*	(0.06)	0.10**	(0.05)
ε_{t-1}^{2}	0.06**	(0.00)	0.07**	(0.00)	0.07**	(0.00)	0.07**	(0.00)	0.03**	(0.01)	-0.03	(0.21)
$\varepsilon_{t-1}^{2} I_{t-1}$	0.04**	(0.00)	NA		0.02	(0.15)	NA		0.06**	(0.00)	0.10**	(0.00)
ε_{t-2}^{2}	NA		NA		NA		NA		NA		0.09**	(0.00)
h_{t-1}	0.92**	(0.00)	0.93**	(0.00)	0.91**	(0.00)	0.92**	(0.00)	0.93**	(0.00)	0.87**	(0.00)
$I^{+}W_t$	0.00	(0.83)	0.00	(0.61)	-0.01	(0.23)	-0.01	(0.20)	0.00	(0.32)	0.00	(0.50)
$I^{-}W_t$	-0.05*	(0.07)	-0.06**	(0.05)	-0.04**	(0.05)	-0.04*	(0.06)	-0.09**	(0.01)	-0.27**	(0.00)
GED	1.37**	(0.00)	1.36**	(0.00)	1.38**	(0.00)	1.38**	(0.00)	1.38**	(0.00)	1.40**	(0.00)
Adj R^2	0.03		0.03		0.02		0.02		0.06		0.06	

Period (distribution)	Model 12 (GED specification)		Model 13 (GED specification)		Model 14 (GED specification)		Model 15 (GED specification)		Model 16 (GED specification)		Model 17 (GED specification)	
AIC	3.81		3.81		4.10		4.10		3.51		3.51	
Log likelyhood	-9869.55		-9874.94		-5270.87		-5271.94		-4565.26		-4561.96	
Q(5)	0.00	(0.43)	0.00	(0.38)	-0.01	(0.65)	-0.01	(0.61)	0.00	(0.91)	0.00	(0.75)
ARCH(5)	8.17	(0.15)	**10.39***	**(0.06)**	3.59	(0.61)	3.84	(0.57)	**10.75***	**(0.06)**	6.58	(0.25)

Note: Please refer to Table 5 for the definitions of the notations.

The sample periods of Models 14 and 15 are from 1986 to 1996, the first sub-sample period. The AIC value, the maximum likelihood value, and the ARCH test results are very close in these two models. The variance equation of Model 14 is asymmetric and the coefficient of the asymmetric factor (δ) is insignificant. To simplify the model, we employ Model 15 as the primary model in the first sub-sample period. This rationale is the same as we discussed in Table no. 6. The sample periods of Models 16 and 17 are from 1997 to 2007, the second sub-sample period. The variance equations in these two models are specified as asymmetric. The major reason is that Model 16 is GJR-GARCH (1, 1) and the ARCH test result for Model 16 is significant, so we adjust Model 17 to GJR-GARCH (2, 1) to satisfy basic econometric requirements. In addition, the maximum likelihood value of Model 17 is larger, so we use Model 17 as the primary model in the second sub-sample period.

As to the variance equations, the coefficients of the low cloud cover are significant and negative, which indicates that low cloud cover reduces the volatility of stock returns and high cloud cover does not. Estimation results of Table no. 7 show that, there exists the asymmetric sunshine effect in the stock return volatility. Estimation results of Table no. 6 prove the existence of the sunshine effect and those of Table no. 7 confirm the impact of the sunshine effect. To understand where the sunshine effect comes from, in the following, we include the low and high cloud cover variables in both the mean and variance equations.

Table no. 8 reports the estimation results of the first and second moment models. Symbol “MV” indicates that both high and low cloud covers are included in the mean and variance equations. The impact of the U.S. stock market performance is still significant in Table no. 8. Models 12MV and 13MV cover the whole sample period. The AIC value, the maxima likelihood value, and the ARCH test all support that Model 12MV is the more appropriate model to use. The estimation result of Model 12MV shows that the coefficients of the cloud cover in both the mean and variance are not significant under the 10% significant level, which indicates that the sunshine effect is suppressed with the consideration of both the first and second moments. The major reason for this result is as follows. The sunshine effect enlarges the volatility of the stock returns; in the meantime, however, the sunshine effect also positively affects the stock returns. The two forces from the sunshine effect might cancel out each other, which leads to the insignificance of the coefficients. To ascertain which moment dominates the impact of the sunshine effect, we estimate the model in the two sub-sample periods separately.

Table no. 8: Estimation results of the first-and-second-moment-sunshine-effect equation

Period (distribution)	Model 12MV (GED specification)		Model 13MV (GED specification)		Model 14MV (GED specification)		Model 15MV (GED specification)		Model 16MV (GED specification)		Model 17MV (GED specification)	
	1987~2007				1987~1996				1997~2007			
Threshold value	τ=1.3		τ=1.3		T=6.7		τ=6.3		τ=1.4		τ=1.4	
	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value	Coeff.	P value
Constant	0.06	(0.26)	0.07	(0.19)	0.17	(0.16)	0.21	(0.09)	0.08	(0.24)	0.05	(0.44)
R_{t-1}	0.03**	(0.04)	0.03*	(0.06)	0.04**	(0.03)	0.04**	(0.04)	0.01	(0.45)	0.01	(0.47)
R_{t-2}	0.06**	(0.00)	0.05**	(0.00)	0.08**	(0.00)	0.07**	(0.00)	0.04**	(0.02)	0.04**	(0.03)
R_{t-3}	0.02*	(0.07)	0.02*	(0.10)	0.04*	(0.06)	0.04*	(0.07)	0.01	(0.54)	0.00	(0.80)
R_{t-4}	-0.02	(0.21)	-0.02	(0.13)	0.00	(0.82)	-0.01	(0.65)	-0.03*	(0.09)	-0.03*	(0.07)
R_{t-5}	0.00	(0.97)	0.00	(0.77)	0.01	(0.78)	0.00	(0.82)	0.01	(0.62)	0.00	(0.83)
$I^{+}W_t$	0.00	(0.63)	0.00	(0.63)	-0.01	(0.45)	-0.01	(0.34)	-0.01	(0.32)	0.00	(0.59)
$I^{-}W_t$	-0.18	(0.21)	-0.18	(0.20)	-0.03	(0.28)	-0.04	(0.16)	-0.18	(0.17)	-0.15	(0.19)
R^{DJ}_{t-1}	0.28**	(0.00)	0.29**	(0.00)	0.16**	(0.00)	0.16**	(0.00)	0.35**	(0.00)	0.35**	(0.00)
Variance Equation												
Constant	0.03	(0.29)	0.03	(0.22)	0.17**	(0.04)	0.14*	(0.08)	0.04	(0.38)	0.09*	(0.09)
ε^2_{t-1}	0.06**	(0.00)	0.07**	(0.00)	0.07**	(0.00)	0.07**	(0.00)	0.05**	(0.00)	-0.04*	(0.07)
$\varepsilon^2_{t-1} I_{t-}$	0.04**	(0.00)	NA		0.02	(0.13)	NA		0.14**	(0.00)	0.13**	(0.00)
ε^2_{t-2}	NA		NA		NA		NA		NA		0.10**	(0.00)
h_{t-1}	0.92**	(0.00)	0.92**	(0.00)	0.91**	(0.00)	0.92**	(0.00)	0.85**	(0.00)	0.84**	(0.00)
$I^{+}W_t$	0.00	(0.80)	0.00	(0.97)	-0.01	(0.22)	-0.01	(0.27)	0.01	(0.33)	0.00	(0.96)
$I^{-}W_t$	-0.15	(0.15)	-0.16*	(0.09)	-0.04**	(0.05)	-0.04*	(0.10)	-0.22**	(0.00)	-0.29**	(0.00)

GED	1.36 **	(0.00)	1.35 **	(0.00)	1.39 **	(0.00)	1.37 **	(0.00)	1.39 **	(0.00)	1.40 **	(0.00)
Adj R^2	0.03		0.03		0.02		0.02		0.06		0.06	
AIC	3.81		3.81		4.10		4.10		3.51		3.51	
Log likelihood	-9869.30		-9874.65		-5270.26		-5271.37		-4565.13		-4557.92	
Q(5)	0.00	(0.42)	0.00	(0.36)	-0.01	(0.62)	-0.01	(0.59)	0.00	(0.83)	0.00	(0.69)
ARCH(5)	7.61	(0.18)	9.59 *	(0.09)	3.72	(0.59)	3.89	(0.57)	10.00 *	(0.08)	6.35	(0.27)

Note: Please refer to Table 5 for the definitions of the notations.

Models 14MV and 15MV cover the first sub-sample period. The results of the AIC value, maximum likelihood value, and the ARCH test are very close in these two models. Since the variance equation of Model 14MV is asymmetrically specified and the coefficients are insignificant, to simplify the model specification, we choose Model 15MV as the major model to be estimated in the first sub-sample period. In this way, we could also compare the estimation result of Model 15MV with that of Table no. 7. Models 16MV and 17MV cover the second sub-sample period. The variance equations of the two models are asymmetrically specified. Since the ARCH test indicates that Model 16MV is significant, we adjust Model 17MV to the GJR-GARCH (2, 1) model to meet the basic econometrics requirements. In addition, because Model 17MV has better goodness of fit, we employ it as the major model in the second sub-sample period.

As shown in Table no. 8, the coefficients of the low cloud cover in the mean equation are negative and insignificant, while those in the variance equation are negative but significant, which indicates that the low cloud cover could reduce the volatility of the stock returns. The high cloud cover does not function in the same way. This finding implies that the asymmetric sunshine effect exists in the stock return volatility and that low cloud cover could impact the stock return volatility, the second moment. This finding is different from the results of Tables no. 5 and 6. It tells us that the sunshine effect is dominated by the second moment: through the co-moment process, the sunshine effect first enlarges the volatility of the stock return and then, affects the stock returns.

As we discussed before, Goetzmann and Zhu (2005) find that the relationship between the sunshine effect and stock returns is not stable, and Hirshleifer and Shumway (2003) find that one could not utilize the weather factors as the trading strategy in the stock market. Our empirical findings can explain why the sunshine effect could not overcome the fundamental factors and the expectations. The primary reason is that the sunshine effect affects the stock returns through the second moment – enlarging the stock return volatility. Although the sunshine also exist in the first moment, its force is much weaker here in the first moment! The sunshine effect detected by previous researches is just an incomplete portion; that is, par of the outcome of the co-moment phenomena between the first and second moments. As what we have explained in Table no. 8, the significant levels of the coefficients of the low cloud cover are higher than those of the high cloud cover in the mean and variance equations, and the coefficients of the low cloud cover are significant only in the variance equation. Therefore, if one only looks at the mean equation, then the discovered impact of the cloud cover would be much weaker than what it should be.

Conclusion

In this study, we investigate the effectiveness of the sunshine effect in Taiwan's stock market with the consideration of the impact of the U.S. stock market, the GED error distribution, and a longer sample period. We employ the cloud cover as a proxy of the sunshine effect to examine the impacts of sample periods and cloudiness. In addition, since the stock return and its volatility have the co-movement phenomena that was not considered by and many previous studies, we would like to make up this gap by including both the first and second moments in our models to examine the sunshine one step further.

The empirical findings are summarized as follows. For the TAIEX index, in the whole and first sub-sample periods, adding the influence of the U.S. stock market would reduce the impact of the weather factor on Taiwan's stock returns, and this is consistent with the finding of Goetzmann and Zhu (2005) that the sunshine effect would not overcome the impact from the economic fundamentals. However, in the second sub-sample period, the cloud cover has significantly negative impact on Taiwan's stock market, even with the inclusion of the influence of the U.S. stock market. In this sample period; the sunshine effect is more effective in the low cloud cover period. In addition, the empirical results suggest that the sunshine effect works differently in different sample periods. Starting from 1997, the sunshine effect is more effective than it was in the previous eleven years. Moreover, we find that the specification of the distribution of the error term would significantly affect the estimation results.

Including the first and second moments in the model, we find that the impact of the sunshine effect on the stock returns is no longer significant but that on the stock return volatility is. This indicates that the sunshine effect works by enlarging the stock return volatility first and then, affects the stock return. This finding could also explain why the sunshine effect cannot overcome the impacts from the economic fundamental factors and people's expectations, and could offer answers to the doubts raised by Goetzmann and Zhu (2005) and Hirshleifer and Shumway (2003) that the sunshine effect is not robust.

The research of the sunshine effect of the stock market belongs to the academic area of behavior economics or finance. In this paper, there are still some details or impact factors that need to be clarified and those are to be studied in our future researches. What we found in this paper could be a useful reference for other researchers.

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Appendix A: Data profiles

Variable	Period	Data resource/code
Average cloud cover (Cloudy)	January 1, 1986 to December 31, 2007	Central Weather Bureau of Taiwan
Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX)	January 6, 1986 to December 31, 2007	JS
Dow Jones Industrial Average index (DJIA)	January 6, 1986 to December 31, 2007	JYN

Note: In addition to the cloud cover whose data come from the Central Weather Bureau of Taiwan, the data of the rest variables come from the AREMOS Database of the Taiwan Economic Data Center.